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DATE: March 11, 1993
TO: Dr. Richard Brandt
FROM: Joseph W. Lyding 
SUBJECT: Semiannual Report, ONR Contract No.: N00014-91-J-1675

Enclosed is the Semiannual Report for the Office of Naval
Research Contract No. N00014-91-J-1675, entitled Cryogenic Ultrahigh Vacuum
Scanning Tunneling Microscopy, for the period of August 1, 1992 to January 31,
1993.

lbh

cc: Administrative Grants Officer
Director, Research Laboratory
Defense Technical Information Center
Lilian Beck
Molly Tracy

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**Semiannual Report
to the
Office of Naval Research**

Contract: N00014-91-J-1675
Title: Cryogenic Ultrahigh Vacuum Scanning Tunneling Microscopy
Principal Investigator: Joseph W. Lyding
Report Period: 8/1/92 - 1/31/93
Scientific Program Officer: Dr. Richard Brandt

Abstract

This report describes recent progress towards the development of a variable temperature cryogenic UHV-STM. The transition from STM-based nanolithography and the loss of a good graduate student (to Stanford) has slowed this project. However, a part-time postdoc has been hired and a new student is being recruited. The apparatus is now essentially complete as a stand alone system, and the testing sequence has begun.

Key Words: Scanning Tunneling Microscopy, Cryogenic Ultra-high
Vacuum STM

Introduction

During the past year the focus of this grant has shifted from STM nanolithography to the development of an easy to use cryogenic UHV-STM. There have been delays in this project due to this change, and because of personnel issues. The students initially supported by this grant are now supported by the URI at Illinois for STM-based nanolithography. Although one very good student was hired for this project last summer, he chose to

accept admission at Stanford starting last Fall. Beginning with the Fall '92 semester, a part-time (25%) postdoc (Anthony Kam) was hired to work on this project. Dr. Kam is in the Medical Fellows program at Illinois, pursuing his MD while performing his postdoctoral duties, which amount to about two days/week. Although medical training would ordinarily preclude additional activities, Tony has special qualifications. He received his PhD in experimental physics from Harvard, graduated as valedictorian in Arts and Sciences from Cornell, and has outstanding letters of recommendation. To date he has designed and constructed the wiring and heatsinking mechanisms of the cryogenic STM, modified the transfer mechanism, and is ready to begin operational testing.

Cryogenic Ultrahigh Vacuum STM Status

The previous report for this project, for the period ending 7/31/92 provided an overview of the construction of the cryogenic UHV-STM shown below in figure 1.

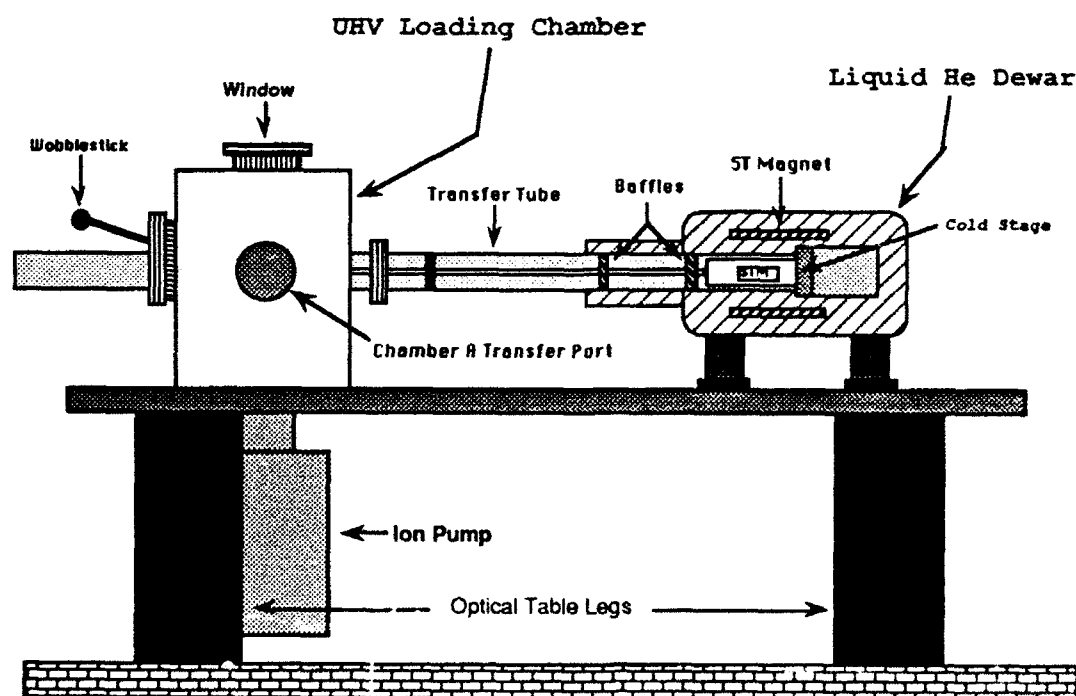


Fig. 1: Diagram showing a side view of the cryogenic UHV-STM.

Listed below is an updated version of that status list.

<u>Cryogenic UHV-STM checklist</u>	<u>7/31/92</u>	<u>Present</u>
Helium dewar with 5T magnet	Finished	Finished
Room temperature loading chamber	Finished	Finished
UHV transfer tube into dewar	Finished	Finished
STM		
Scanning Head	Finished	Finished
Coarse Translation	Finished	Finished
Mounting and transfer mechanism	Testing	Finished
Wiring Connectors	Finished	Finished
Wiring	Not Finished	Finished
Vacuum pumps		
Ion pump	Ready for installation	No change
Turbo pump	Ready for connection	No change
Chamber A transfer mechanism	Not installed	No change
Mounting table with suspension	Finished	Finished

The "no change" items require very little effort and will be implemented when the cryogenic UHV-STM is ready for connection to the existing UHV-STM system. The following checklist will be used to track the progress towards a finished system.

<u>Cryogenic UHV-STM test sequence</u>	<u>Status</u>
Bench test scanning head	Done
Test STM in final mounting configuration	in progress
Test operation under vacuum conditions	not done
Test operation under LN ₂ and vacuum conditions	not done
Test operation under liquid helium and vacuum conditions	not done
Electropolish all parts for UHV operation	partially done
Install ion pump and test cryogenic UHV operation	not done
Connect to existing UHV-STM system	not done

Much of the low temperature and vacuum testing will borrow from our experience with our currently operational cryogenic vacuum (non-UHV) STM system. During the coming summer, Dr. Kam will have no medical school obligations and will be dedicated 100% to this project. By the end of summer, a full time graduate student should have been hired on this project. As discussed previously, the scanning head of the cryogenic UHV-STM system will have coarse translation capability to register features of interest within the scan window. This coarse translation capability has already been tested successfully at cryogenic temperatures in the operational low temperature STM system and in the existing room temperature UHV-STMs. Shown in figure 2 is a high resolution scan of a GaAs/AlGaAs superlattice, grown by MBE and cleaved in UHV. The coarse translation system was used to position the tip over the superlattice region. We find no degradation of STM operation by including coarse translation. Currently, our room temperature UHV-STMs exhibit 0.02 \AA vertical resolution (limited by electronic noise) and thermal drift of $\sim 2 \text{ \AA/hour}$.

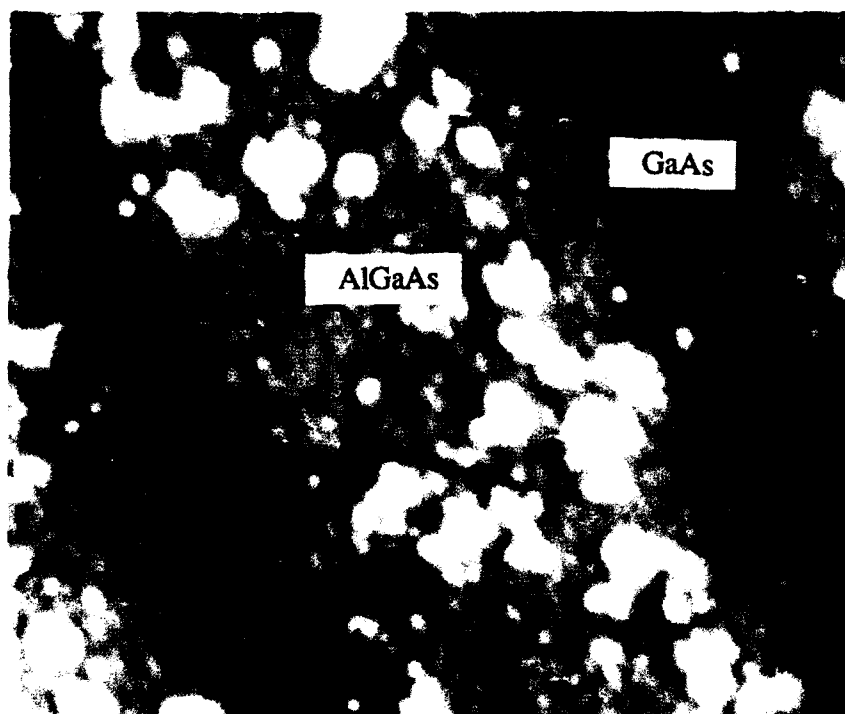


Fig. 2: UHV STM image of a cleaved III-V heterolayer crystal, demonstrating the use of the STM coarse translation system.